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# FROM ENERGY STRATEGIES THROUGH ENERGY RETROFITTING TO FIRE SAFETY OF BUILDINGS

Ivana Banjad Pecur[a], Borka Bobovec[b], Bojan Milovanovic[a], Marina Alagusic[a]

[a] University of Zagreb, Faculty of Civil Engineering, Department of Materials, Zagreb, Croatia
[b] Ministry of Construction and Physical Planning of Republic of Croatia, Zagreb, Croatia

## Abstract

European policy is reflected in a 10-year strategy called 2020 proposed to revive European economy and it is deeply interconnected with Energy Performance of Building Directive and its Recast. Republic of Croatia, as an EU member state, is aligning its national energy policy with European policy. By boosting energy retrofitting of existing and constructing energy efficient new buildings, thermally enhanced building envelope represents significantly increased fire load on building, thus fire safety becomes inevitable segment of energy efficiency of buildings. Croatia has no national test method for determining fire performance of building façade, while harmonized EN test method is currently being developed. In this paper an overview and comparison of BS 8414-1:2002 and DIN Entwurf 4102-20 standards will be presented, since they are proposed as a basis for future harmonized EN test method. For similar configuration of test specimens, BS 8414-1:2002 defines significantly more severe heat exposure compared to DIN Entwurf 4102-20.

**Keywords:** energy retrofitting, building facade, fire safety, fire performance test methods, BS 8414-1:2002, DIN Entwurf 4102-20

## 1 INTRODUCTION

European policy is reflected in a strategy called Europe 2020 proposed to revive economy, which identifies five headline targets the EU should take to boost growth and employment (European Commission, 2010). One of the five headline targets refers to the 20-20-20 goals which are deeply interconnected with Energy Performance of Building (EPBD) Directive (2002 and recast in 2010) (European Parliament, 2010). Republic of Croatia, as a full EU Member State is obliged to fulfil all the obligations posed for sustainable and smart growth and development (Ministry of Construction and Physical Planning, 2012). In terms of the legal framework for energy efficiency in buildings, with Building Act (Croatian Parliament, 2013) and by implementation of EPBD, basic requirements for buildings including energy economy and heat retention are defined. In that way, the basis for a bylaw detail regulation in area of energy efficiency is given. In order to fulfil commitments, Croatia is aligning its national energy policy with an EU policy, through Energy Saving Legislation and Instruments on national level. Third National Energy Efficiency Action Plan for Period 2014 – 2016 comprises evaluation report on implementation of energy efficiency policy, determines the energy savings in the preceding three-year period and provides guidance for the following period with detailed official proclamation of the planned measures (Government of the Republic of Croatia, 2014). In order to strengthen national energy policy and to encourage investments, Long-term Strategy for Mobilising Investment in the Renovation of the National Building Stock of the Republic of Croatia is defined (Government of the Republic of Croatia, 2014).

Investments in a sustainable refurbishment of buildings generate wider economic benefits which exceed the effects of energy savings itself; an increase in construction activity will inevitably impact the GDP, employment and income for the state budget. Furthermore, the improvement of living and work conditions will primarily affect human health, alleviating energy poverty, increase property values, increase consumption, GDP and employment (Ahec-Šonje et al., 2014). Housing, and thus the construction of buildings are the most important components of social and economic development of a society, spatial organization and development and raising the living standards of the population. At the same time, housing is the biggest user of space and the predominant content of the settlement. Because of that housing deserves the greatest attention in the planning, design and construction, regardless of whether they are individual, entrepreneurial or social efforts to provide housing space (ApolitikA, 2012). High quality construction and interior design protects the end user, but also implies the responsibility of all participants in the realization of the principle of sustainable development, therefore, durability, energy efficiency, environmental compatibility and preservation of health. Ensuring high quality energy refurbishment can happen only with the promotion of innovation, the establishment of mechanisms of supervision and quality control as well as raising awareness of the construction sector of the importance of high-quality design and quality performance. As presented above, stock market of sustainable energy efficient renovation is gaining strong momentum in Croatia, as it has already caught other EU countries. Direct results of that are thermally enhanced envelopes which, due to materials used, represent significant increase in fire load on a building and raise questions about the fire safety of building. Thus fire safety becomes inevitable segment of energy efficiency of buildings and second Basic requirement for construction works *Safety in case of fire* and sixth Basic requirement for construction works *Energy economy and heat retention* (European Parliament, 2011) are becoming strongly intertwined.

Croatia has no national test method for determining fire performance of building façade, but there is also no unique test method on EU level. Across the EU there is a number of test methods for determining fire performance of building envelope, hence experts seek to establish harmonised EN test method by which evaluating fire performance of a building façade in today's period of energy efficiency would be uniform in all European countries. In this paper an overview and comparison of some existing European test methods, such as BS 8414-1:2002 and DIN Entwurf 4102-20, will be presented, since these are the most commonly used test methods in Europe and future harmonised EN test method most likely will be tracing those methods.

## 2 OVERVIEW AND COMPARISON

This paper is dealing with present need and efforts that are put into establishment of harmonised EU test method for determining fire performance of façade, i.e. building envelope in a fire scenario room fire emerging through the opening to facade. By literature review, it has been noticed that the most commonly used test methods for determining fire performance of building façades are British standard BS 8414-1 (BSI, 2002) and German standard DIN Entwurf 4102-20 (DIN, 1998). Therefore, European Commission has requested from European Organisation for Technical Assessment (EOTA) to develop harmonised EU test method that will be tracing those two previously mentioned standards (Kotthoff, 2015). The main idea is to distinguish fire behaviour on a material level and on a building level. Fire behaviour, i.e. fire performance on a material level is appropriately determined with methods defined in the Euroclass classification (HZN, 2010). However, reaction to fire classification based on those methods is not adequate and cannot fully describe fire performance on a building level. In other words, fire performance of a building façade comprises significantly more parameters than only reaction to fire of materials used for a façade. Parameters such as fire spread, contribution to fire, max. dimensions of a flame spread, temperature - time characteristics, continuous smouldering and glowing combustion, mechanical performance including falling of burning droplets/particles, collapse of a cladding system and areas damaged by fire in all layers assessed by post-test analysis should be included in determining fire performance of a building façade (Kotthoff, 2015). When parameters set out above describe real fire performance of a building façade, i.e. fire behaviour corresponding to the behaviour of a building in a real fire, they have to be obtained in a test method that is a simulation of a real fire situation and which can ensure repeatability of testing. Thereby, suitable test method is a full scale test. Standards BS 8414-1 and DIN Entwurf 4102-20 are both full scale tests but they differ substantially in a size of a test specimens, fire load (fire exposure), test procedure and evaluation criteria. Their comparison regarding to the most important characteristics is shown in Table 1.

Table 1 Comparison of BS 8414-1:2002 and DIN Entwurf 4102-20 test methods for determining fire performance of a building façade (BSI, 2002; White et al., 2014)

| Characteristics | Standard / Test method | |
|---|---|---|
| | BS 8414-1:2002 | DIN Entwurf 4102-20 |
| Scope | Assessing the behaviour of non-loadbearing external cladding systems, rainscreen overcladding systems and external wall insulation systems when applied to the face of a building and exposed to an external fire under controlled conditions. The fire exposure is representative of an external fire source or a fully-developed (post-flashover) fire in a room, venting through an opening such as a window aperture that exposes the cladding to the effects of external flames. | |
| Principle | The external cladding system (ECS) is applied to a vertical external surface simulating the face of a building in the form of a main face together with a return wing. The façade installed is representative of the end use with all insulation, cavity air gaps, fixings and window details. At the base of the main vertical wall an opening is provided through which the fire can vent. A fully developed fire in a room abutting the external face of a building venting through a broken window is simulated. The extent of damage caused to the ECS, and in particular the ability for the ECS to resist the propagation of the fire upwards, is evaluated. | |
| Size of a test specimen | L-shaped;<br>Main test wing: min 2.6 m long;<br>Other leg: min 1.5 m long;<br>Height: min 8 m | L-shaped; Main test wall: min 2 m long (burner) or 1.8 m long (wood crib); Other leg: min 1.4 m long (burner) or 1.2 m long (wood crib); Height: min 5.5 m |
| Substrate | Masonry | Light weight concrete |
| Combustion chamber | Positioned at the base of the main vertical test wall such that the fire can project through the opening at the base of the main vertical test wall. | |
| | The opening shall be (2000±100) mm high and (2000±100) mm wide. The combustion chamber shall have a volume of at least 4.275 $m^3$ and shall have internal dimensions of at least 1900 mm wide, 1000 mm deep and 2250 mm high. | The fire enclosure and opening is nominally 1000 mm wide x 1000 mm high. |
| Heat source | Annex A: Fuel source with heat flux of (45-95) $kW/m^2$ over a continuous 20 min period.<br>Annex B: A 400 kg timber crib nominally 1500×1000 mm in plane and 1000 mm high of softwood sticks with nominal dimensions of 50×50 mm cross-section and nominal lengths of 1500 and 1000 mm. Nominal total heat output of the heat source is 4500 MJ over 30 min at a peak rate of 3±0.5 MW | The fire source is a 320 kW constant HRR linear gas burner located approx. 200 mm below the opening soffit. A 25 kg timber crib, 500×500×480 mm, using 40×40 mm softwood sticks was previously used as the fire source. The fire source achieves a max. temp. of approx. 780-800°C measured 1 m above the opening soffit on a non-combustible wall. |
| Test duration | The nominal duration of the burning of the heat source shall be 36 min. If any part of the cladding system is still burning 30 min after heat source ignition continue taking records for a max. time of 60 min. Otherwise, terminate the test 30 min after the ignition of the heat source. | The gas burner is turned off after 20 minutes for combustible facades and 30 min for non-combustible facades. Measurements and observations continue until all burning and smoke production ceases, or until 60 minutes. |

The height of the BS test specimen is greater and its heat exposure is more severe than the one defined in DIN standard, Figure 1. More precisely, heat exposure at peak rate defined in BS standard (3000 ± 500 MW) is approximately 10 times greater than heat exposure defined in DIN standard (320 kW). Heat exposure in DIN standard is a constant fire load, without peak. If real room with standard furniture inside is observed, its fire load is between 500 and 800 $MJ/m^2$ which for reference scenario room of 20 $m^2$ gives total fire load between 10000 and 16000 MJ (Vuić, 2013). Other authors gave range of heat release rate for furnished living room as 4000 – 8000 kW (Milke et al., 2002). Therefore, it can be stated that due to fire load, i.e. heat exposure BS standard is a more reliable test method, since it realistically simulates expected fire load in a real living or office room. However, depending on a building type, i.e. use of building there are rooms with lower fire load for which BS standard would be unnecessarily too strict and too demanding. In that case, standards with lower fire load would be more suitable, e.g. DIN standard.

Since test facilities are different in BS and DIN standard, accordingly performance criteria for determining fire performance are also different for BS and DIN standard, Table 2.

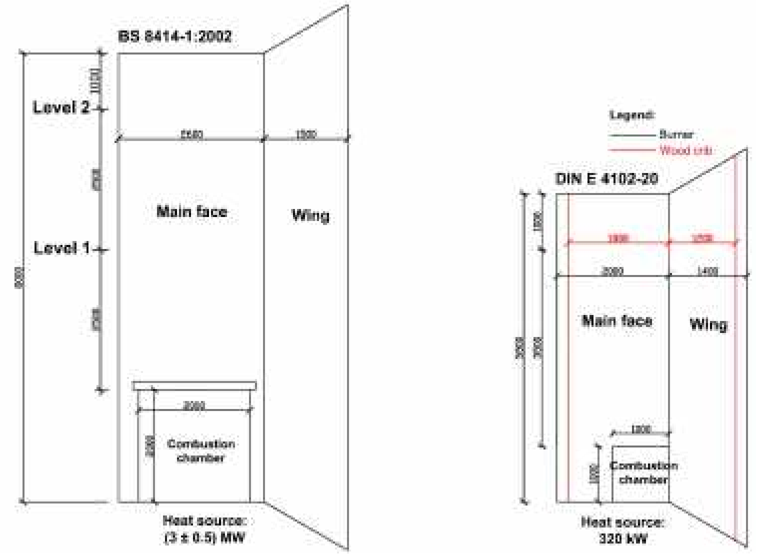

Fig. 1 Comparison of test specimens according to BS (left) and DIN (right) standard

Table 2 Performance criteria for BS 8414-1:2002 and DIN Entwurf 4102-20 (BRE Global, 2009; BRE Global, 2012; White et al., 2014)

| Test | Performance criteria |
|---|---|
| BS 8414-1:2002 | *External fire spread* Failure to external fire spread is deemed to have occurred if the temperature rise above start temperature $T_s$ of any of the external thermocouples at level 2 exceeds 600°C, for a period of at least 30 seconds, within 15 min of the start time $t_s$. |
| | *Internal fire spread* Failure due to internal fire spread is deemed to have occurred if the temperature rise above $T_s$ of any of the internal thermocouples at level 2 exceeds 600°C, for a period of at least 30 seconds, within 15 min of the start time $t_s$. |
| | *Mechanical properties* No failure criteria have been set for mechanical performance. However, details of any system collapse, spalling, delamination or flaming debris should be included in the test report. The nature of the mechanical failure should be considered as part of the overall risk assessment when specifying the system.<br>These observations shall be taken for at least 30 min or for the duration of any burning of material in the wall system, whichever is the shortest time, for a maximum time of 60 min. |
| DIN Entwurf 4102-20 | No ”burned’’ damage (excluding melting or sintering) at a height of 3.5 m or more above the opening soffit. |
| | Temperatures on the wall surface or within the wall layers/cavities must not exceed 500°C at a height of 3.5 m or more above the opening soffit. |
| | No continuous flaming for more than 30 s at a height of 3.5 m or more above the opening soffit. |
| | No flames to the top of the specimen at any time. |
| | Falling of burning droplets and burning and non-burning debris and lateral flame spread must not exceed 90 s after the burners are turned off. |

Different test set up, as shown in Table 1, and different performance criteria, as shown in Table 2, can lead to the different fire performance evaluation for the same building façade, e.g. for the same system used in a case of External thermal insulation composite systems (ETICS) applied on the external wall of building. The worst case scenario is that, e.g. the same ETICS system to “fail’’ according to one test method and to “pass’’ according to other test method, Table 3.

When times of specific appearances from Table 3, such as flaming on the surface and droplets, on identical ETICS systems are observed, it can be noticed that flaming on the surface and droplets occur earlier on systems tested by DIN standard compared to the identical systems tested by BS standard, despite significantly higher fire load defined in BS standard. As expected, max. recorded heights of flames are higher on systems tested by BS standard than those tested by DIN standard.

Conducted research on fire performance of ETICS systems and their evaluation by BS and DIN performance criteria respectively (BRE Global, 2012), has shown that the ETICS systems with the same thickness of a combustible thermal insulation can “pass’’ if tested by one standard (in this case by DIN standard) and can “fail’’ if tested by another standard (in this case by BS standard).

Table 3 Example of comparison of fire performance of external thermal insulation for walls of multi-storey building according to BS 8414-1:2002 and DIN Entwurf 4102-20 (BRE Global, 2012)

| Standard | EPS | Position of fire barrier (above opening) | Height of fire barrier | Adhesive | Anchors | Mesh | Render | Pass / Fail | Flaming on the surface | Droplets (min after test start) | Pool fire (min after test start) | Max. recorded height of flame |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BS | 300 mm | 0 m & 2.7 m | 200 mm | yes | no | yes | organic | fail | After 5:44 min | 7:35 | 14:20 | 5m |
| DIN | 300 mm | 0 m & 3 m | 200 mm | yes | no | yes | organic | pass | After 1:30 min | no | None recorded | 3m |
| BS | 300 mm | 0 m & 3 m | 500 mm | yes | no | yes | organic | fail | After 3:55 min | 10:39 | 10:56 | 3.5m (6m behind render coat) |
| BS | 200 mm | 3 m | 200 mm | yes | yes | yes | organic | fail | After 4:15 min | 8:08 | 8:49 | 5 m |
| DIN | 200 mm | 3 m | 200 mm | yes | yes | yes | organic | fail | After 3:00 min | 7:44 | 9:35 | 4 m (intermittent 4.2 m) |

In other words, absence of harmonised EU test method for evaluating fire performance of a building façade opens the possibility that the same ETICS system can be used in one country for the specific category of buildings but it cannot be used in another country for that same specific category of buildings, due to different national test methods.

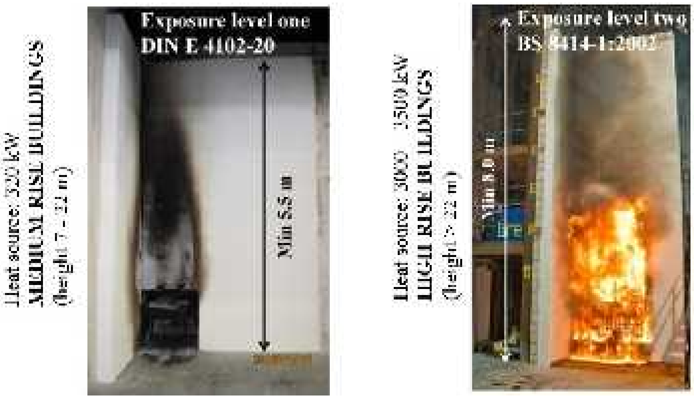

Fig. 2 Possible basis for the future harmonised EU test methods (BRE Global, 2012)

As presented previously, BS and DIN standards differ substantially in a size of a test specimen and severity of the heat exposure (heat source). Hence, they also differ substantially in a performance criteria, thus the same façade system can be evaluated different, i.e. contrary regarding to its fire performance (“pass”/”fail”). Therefore, it has to be noted that BS and DIN standards are not suitable for the same building category, i.e. they do not represent realistic fire performance of a façade for the same building category. Buildings have to be categorized depending on their type (use of building) and height, thus for every category one suitable test method for determining fire performance with representative fire exposure and performance criteria should be defined. Figure 2 presents possible basis for the future harmonised EU test methods for determining fire performance of a building façades, depending on a building category.

## 4 CONCLUSIONS

Absence of harmonised EU test method for determining fire performance of building façade and therefore presence of a number of national test methods are a barrier to trade for the European

Common Market of construction products and may cause unequal level of fire safety for the same type and height of buildings across the EU, since the different national test methods have different test set up and different fire performance criteria. Thereby, fire performance of the façade systems can be fully and equally assessed across the whole EU by taking into account building type (level of fire load) and building height, thus performing harmonised medium or large scale test, i.e. full scale test as Kotthoff suggested (Kotthoff, 2015). Authors of this paper strongly support this approach and consider DIN Entwurf 4102-20 as a suitable basis for the future harmonised EU test method for the medium-rise buildings (height 7 – 22 m) and BS 8414-1:2002 as a suitable basis for the high-rise buildings (height > 22 m), i.e. for determining their fire performance.

It has to be highlighted, that further research in area of fire safety of building façades is needed in order to improve and optimize existing standards and based on them to establish harmonised EU methodology for determining fire performance of a building façade subject to fire scenario, building type, height and eventually to the type of a building facade (ETICS, ventilated façade, etc.).

## REFERENCES

Ahec-Šonje, A., Čeh-Časni, A., Vizek, M. 2014. *The Effect of Housing and Stock Market Wealth on Consumption in Emerging and Developed Countries*. *Economic Systems*, 0939-3625, p.433-450

*ApolitikA, 2012. Arhitektonske politike Republike Hrvatske 2013-2020., ApolitikA, Nacionalne smjernice za vrsnoću i kulturu građenja*, Editor Knifić Schaps, H., Hrvatska komora arhitekata; Ministarstvo graditeljstva i prostornog uređenja, p.79-80, Zagreb, Republic of Croatia

BRE Global, 2009. *Revision of BR135 'Fire Performance of external thermal insulation for walls of multi-storey buildings'*- Second Edition – Draft for Comment, Watford, U.K.

BRE Global, 2012. *A comparison of BS 8414-1 & -2, draft DIN 4102-20, ISO 13785-1 & -2, EN 13823 and EN ISO 11925-2*, Report number CC275194 issue 2, Watford, U.K.

BSI 2002. BS 8414-1:2002 *Fire performance of external cladding systems. Test methods for non – loadbearing external cladding systems applied to the face of building*, British Standards, U.K.

Croatian Parliament, 2013. *Zakon o gradnji*, Narodne Novine 153/2013, Zagreb, Republic of Croatia

DIN 1998-03. DIN Entwurf 4102-20 *Brandverhalten von Baustoffen und Bauteilen - Besonderer Nachweis für das Brandverhalten von Außenwandbekleidungen, als Bestandteil der Zulassungsgrundsätze des Deutschen Instituts für Bautechnik*, Berlin, Germany

European Commission 2010. *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the regions Energy 2020 A strategy for competitive, sustainable and secure energy*, COM(2010)639 final, Brussels, Belgium

European Parliament, Council of the EU 2010. *Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (recast)*. *OJEU*, L 153/13

European Parliament, Council of the European Union 2011. *Regulation (EU) No 305/2011 of the European Parliament and of the Council of 9 March 2011 laying down harmonised conditions for the marketing of construction products and repealing Council Directive 89/106/EEC*. *OJEU*, L 88/5

Government of the Republic of Croatia, 2014. *Dugoročna strategija za poticanje ulaganja u obnovu nacionalnog fonda zgrada Republike Hrvatske*, Narodne Novine 74/2014, Zagreb, Republic of Croatia

Government of the Republic of Croatia, 2014. *Treći Nacionalni akcijski plan energetske učinkovitosti za razdoblje 2014.-2016.*, Zagreb, Republic of Croatia

Kotthoff, I. 2015. *Large Scale Fire Performance Testing of External Wall Cladding Systems*, Draft EOTA TR 073, Presentation at AG Fire Meeting, Brussels, Belgium

Milke, J., Kodur, V., Marrion, C. 2002. *A Overview of Fire Protection in Buildings*, Federal Emergency Management Agency, USA

Ministry of Construction and Physical Planning, 2012. *Izvješće o stanju u prostoru Republike Hrvatske*, Zagreb, Republic of Croatia

HZN 2010. EN 13501-1:2010 Fire classification of construction products and building elements -- Part 1: Classification using data from reaction to fire tests (EN 13501-1:2007+A1:2009), Croatia

Vuić, T. 2013. *Reakcija na požar povezanih sustava za vanjsku toplinsku izolaciju (ETICS) na osnovi ekspandiranog polistirena i na osnovi mineralne vune*, Specialist postdoctoral thesis, University of Zagreb Faculty of Civil Engineering, Zagreb, Republic of Croatia

White, N., Delichatsios, M. 2014. *Fire Hazards of Exterior Wall Assemblies Containing Combustible Components*, Fire Protection Research Foundation, Victoria, Australia